JMP Instructional data set 006

Semiconductor Sheet Resistance Gauge Study

JMP platforms and statistical methods

Graph Builder: Comparative dot plots; line graph

Problem statement

Electrical resistance is a critical performance metric that is used to evaluate the quality of semiconductor wafers used in chip manufacturing. A common device used to measure this characteristic is a four-point probe. To measure sheet resistance, four electrodes are placed onto the surface of the wafer. Electric potential is applied to two of the electrodes, and the electric current flowing through to the other two is measured.

Engineers in one of the labs that uses this measurement device are concerned that there may be factors that could result in inaccurate measurements. The main concern they have is that residual material may build up on the probes resulting in an incorrect reading on subsequent film that is measured. It is of particular concern when the films are of different materials. A step that can be taken is to condition (i.e., clean) the probes prior to each use. Since it adds time to the measurement process, it is only done periodically in practice.

Another consideration they have is that perhaps different operators of the device may not be following the exact same measurement protocol and are producing different results, specifically an experienced user vs. a new user.

The engineers design an experiment to test these conditions. The experimental design is as follows:

	Probe Conditioning			
	No		Yes	
	Operator		Operator	
Wafer	Experienced	New	Experienced	New
1	2	2	2	2
2	2	2	2	2
3	2	2	2	2
4	2	2	2	2
5	2	2	2	2
6	2	2	2	2

Each of the 6 wafers used in the study is measured under four different scenarios – probes conditioned or not before making the measurements, and the measurements being made by the experienced or new operator. This results in 24 unique treatment combinations of wafer, operator and conditioning. 2 separate measurements are made for each treatment combination resulting in a total of 48 total measurements.

The experimental procedures followed:

1. Six Titanium Nitride film wafers are selected for the study.
2. One Tungsten film wafer will be used as the alternate film to test for residual material remaining on the probes.
3. Before each experimental run, the four-point probe is used to make ten readings on various parts of the Tungsten film. Electric resistance is not recorded for this step as it's merely done as the means to generate the potential residual material on the probes.
4. One of Titanium Nitride wafers, operators, and conditioning (Yes/No) is randomly selected.
5. A single sheet resistance measurement is made.
6. This random assignment continues for all 48 experimental runs.

Data

Semiconductor_Sheet_Resistant_Gauge_Study.jmp

Test Order	The random order in which all measurements were made (1, 2,…, 48)
Wafer	ID of wafer (1, 2,…, 6)
Operator	The operators' experience level (Experienced, New)
Probe Conditioning	Probe conditioning step before measurement (Yes, No)
Resistance	The sheet resistance produced by the gauge (Ohms)

Exercises

The exercises consist of creating a variety of different visualizations of the data. All the graphs that will be created are dot plots with connected lines. The different graphs are alternative ways to display the data. As you'll see, certain visualizations will be better suited at illustrating specific features in the data than others.

1. Create a dot plot with lines connected displaying 'Resistance' on the Y axis, probe condition and operator on the X axis, and the 6 wafers as separate panels.

   Instructions:
   Use Graph Builder. Place the variable 'Resistance' on the Y axis. Place 'Probe Conditioning' on the X axis. Place 'Operator' also on the X axis, but on the outside of 'Probe Conditioning' (Drag the 'Operator' variable to the blue trapezoid region below where the 'Probe Conditioning' tile is). Place 'Wafer' on the top (Group X) region. Add the connect line to the graph by selecting the line icon from the graph palette while holding the shift key down to also include the points. Save this graph to the data table by selecting Save Script > to Data Table under the top red triangle menu.

2. Change the graph created in the previous exercise so that the 'Operator' variable is on the inside level of the X axis and 'Probe Conditioning' on the outside.

   Instructions:
   Grab one of the variable names on the X axis and drag it to the other position. Save this graph to the data table using a different name.

3. Create a dot plot with lines connected displaying the 'Resistance' on the Y axis, 'Wafer' on the X axis, 'Probe Conditioning' as separate panels, and 'Operator' in the Overlay role.

   Instructions:
   Use Graph Builder. Drag each variable into their respective roles. Add the connect line to the graph by selecting the line icon from the graph palette while holding the shift key down to also include the points.
   Save this graph to the data table using a new name.

4. Change the graph created in the previous exercise so that the 'Operator' are the panels and 'Probe Conditioning' is in the Overlay role.

   Instructions:
   Easiest way to do this is to right click on 'Operator' or 'Probe Conditioning' in their respective roles on the graph and choose Swap and select the other variable from the list. Save this graph to the data table using a new name.

5. Create a graph that displays the range between the 2 measurements made by each ‘Operator’ on each ‘Wafer’ for each ‘Probe Conditioning’.

> ***Instructions:***
> *Use Graph Builder. Place the variable ‘Resistance’ on the Y axis. Place ‘Operator’ on the X axis. Place ‘Place ‘Wafer’ in the Group X role. Place ‘Probe Conditioning’ in the Overlay role.*
> *Add the connect line to the graph by selecting the line icon from the graph palette while holding the shift key down to also include the points.*
> *In the Control Panel on the left, select Range under Summary Statistics for both the Points and the Line.*

6. Examine all the graphs created in Exercises 1-5. Recall that all the graphs are essentially plotting the same information in different arrangements. What do the results of this experiment indicate regarding the potential effects that ‘Probe Conditioning’ and ‘Operator’ has on producing consistent electric sheet resistance values? (i.e., Where is the largest source of variability between the repeat measurements?). Do these data indicate that the measurement device is able to produce accurate sheet resistance values? (i.e., Are the measured sheet resistance values obtained from the device, on average, equal to the true sheet resistance of the wafers?).

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